

US MDP Bi-2212 program progress – two updates

- 1. International collaboration on the cable transverse pressure measurement**
- 2. 2212 CCT 5T/14.6T magnetic designs**

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International collaboration – renewed cable mechanical tests at U. Twente

- A EUCARD2 task, with CERN supporting powder fabrication at Nexans. Now renewed with NHMFL and LBNL engaged.
 - Existing samples are ~10 mm wide FNAL cables made using the OST wires ~~with Nexans' lot 82 powder, now known to have hard particles~~. Samples reacted at NHMFL with 50 bar OPHT.
 - Test at Twente led by Simon Otten and Marc Dhalle.
- Ongoing negotiations with CERN (David Larbalestier) for additional tests with the modern B-OST wires with Engi-mat nano-spray combustion powder.
 - 4.5 m long of the LBNL cable #1088 used in the record performance RC5/6 racetrack coils.

(S. Otten, M.S. thesis)

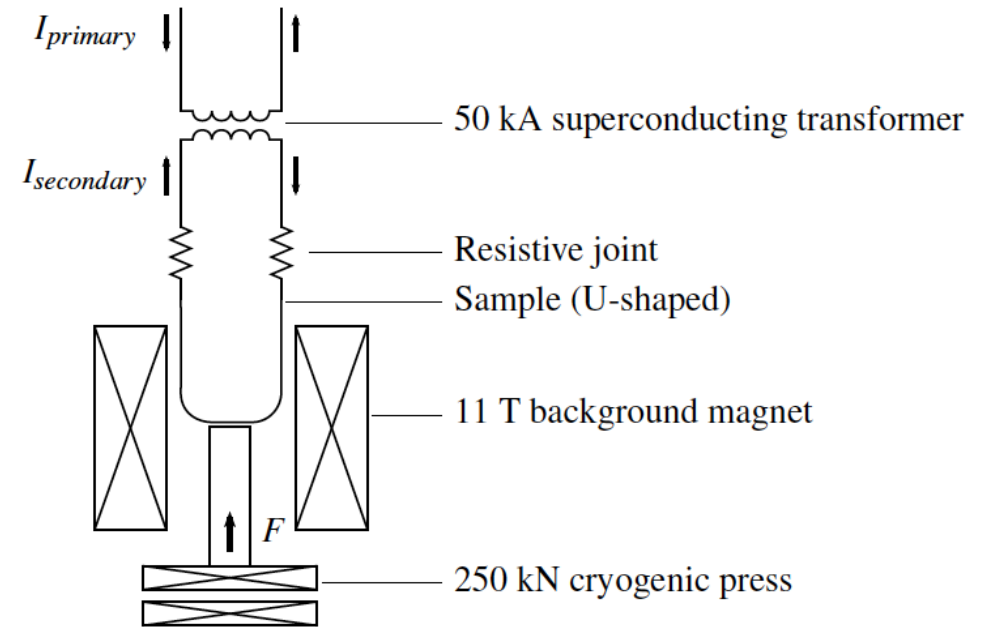


Figure 6.1: Scheme of the press set-up.

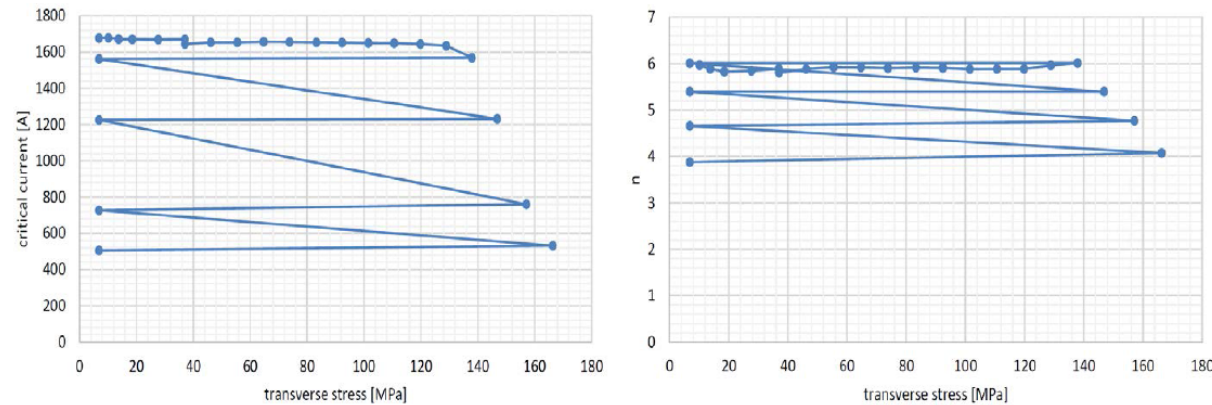
Transverse stress test (averaged data)

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- $T = 4.2 \text{ K}$; $B_{\text{appl}} = 5 \text{ T}$; $E_c = 10^{-4} \text{ V/m}$ ($V_c = 4.6 \text{ } \mu\text{V}$)



- $\sim 5\%$ degradation at 138 Mpa ; 65% degradation at 166 MPa

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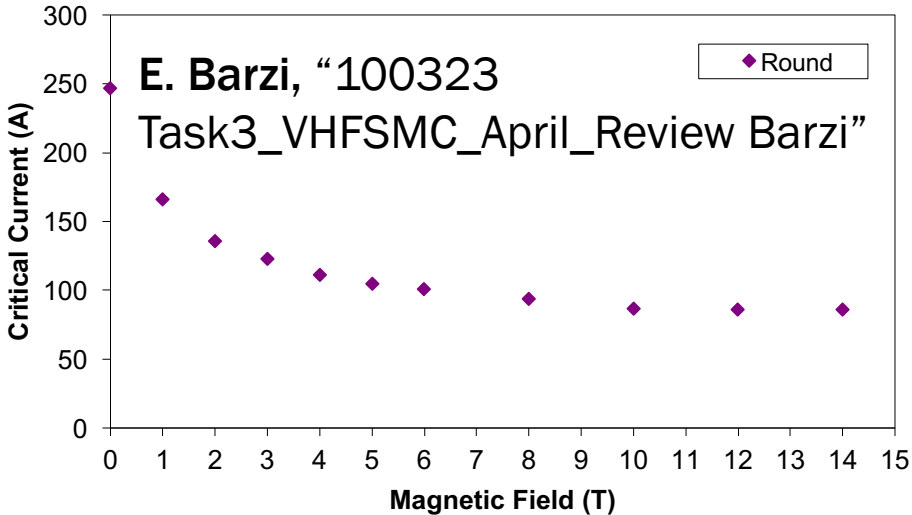
- Sample was potted with CTD-101K.

The first cable Twente examined is a Fermilab VHFSMC cable made with CDP2005 strand with SCI powder; the same strand used in LBNL HST-SC-04/06.

CABLE ID	No. Strands	Strand Size mm	Ave. Thickness mm	Ave. Width mm	Lay Angle deg.	Packing Factor %	Length m
R&DT_090520_24_4 (PMM051221)	24	0.8007	1.507	10.22	15.3	81.5	12
	24		1.488	10.19	15.2	82.5	8
	24		1.449	10.13	15.2	84.9	8
	24		1.414	10.09	15.4	87.7	8.6



OST 051221-1 85x7 SCI powder



1 bar reaction by OST, I_c measurement by Fermilab.

Supercond. Sci. Technol. 23 (2010) 034022

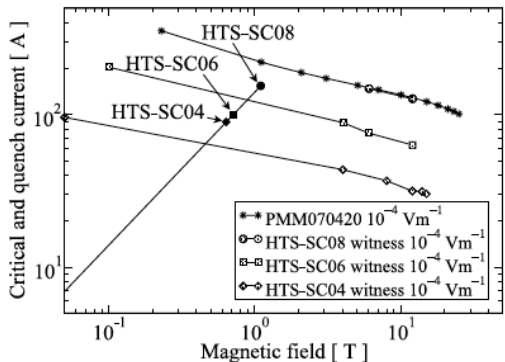


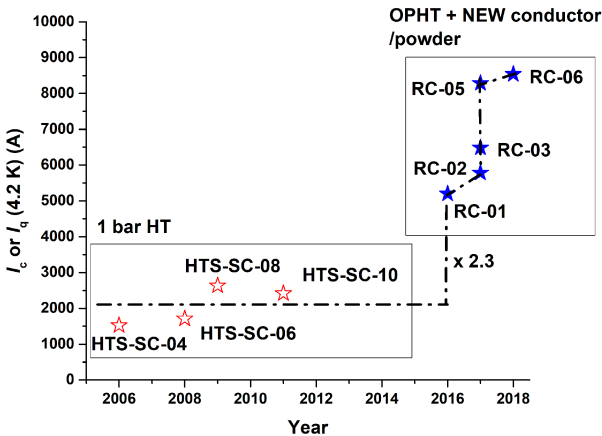
Figure 7. Comparison of coil performance and the witness sample $I_c(B)$ data. The points are measured and the lines are a guide to eye.

Table 4. Summary of coil I_c values at 10^{-4} V m $^{-1}$ and $T = 4$.

	HTS-SC04		HTS-SC06		HTS-SC08	
	I_c (A)	n -value	I_c (A)	n -value	I_c (A)	n -value
Total coil	1526	14	1711	17	2636 ^a	—
Layer 1 total	1564	16	1702	17	2636 ^a	—
Layer 1 inner turn	1290	11	1580	14	2608	23
Layer 1 outer turn	1323	10	1740 ^b	19	2636 ^a	—
Ramp layer 1 to 2	1319	17	1635 ^c	15	2589	24
Layer 2 total	1481	14	1727	17	2636 ^a	—
Layer 2 inner turn	1506	14	— ^a	—	2557	18
Layer 2 outer turn	— ^d	—	1738 ^b	18	2636 ^a	—

^a Quench value. ^b Outer two turns. ^c Transition and coil 2 inner turn combined. ^d Open contact.

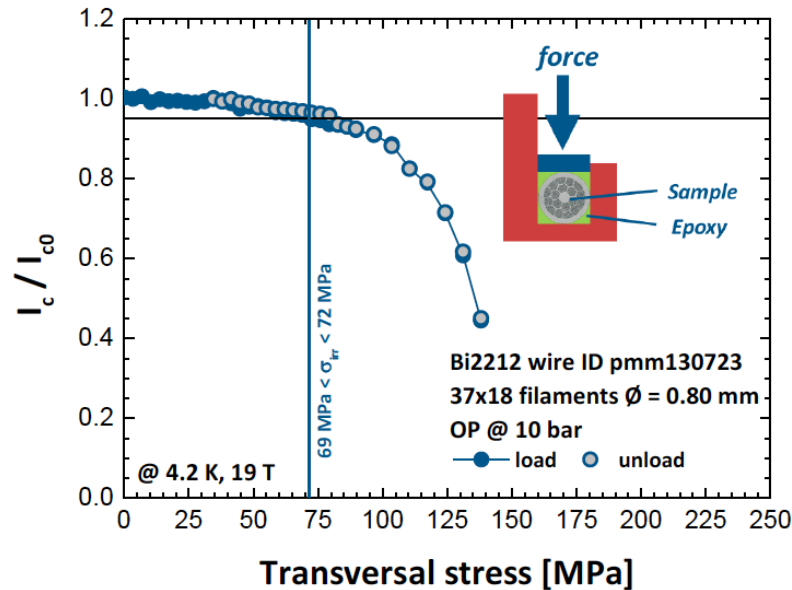
LBNL's subscale racetrack coil



The Twente results not yet reconcile with the transverse pressure experiment on single strand at the Uni. Geneva

- Note – The strand investigated was made with the infamous Nexans batch 82 powder that has hard particles.

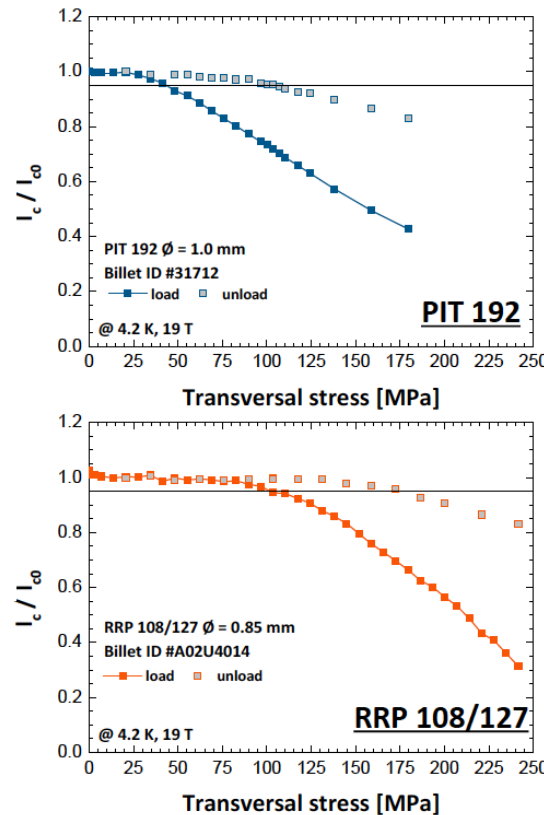
A flavour of HTS: transverse stress sensitivity of Bi2212 wires



$$I_{c0}(B=19T) = 135 \text{ A}$$

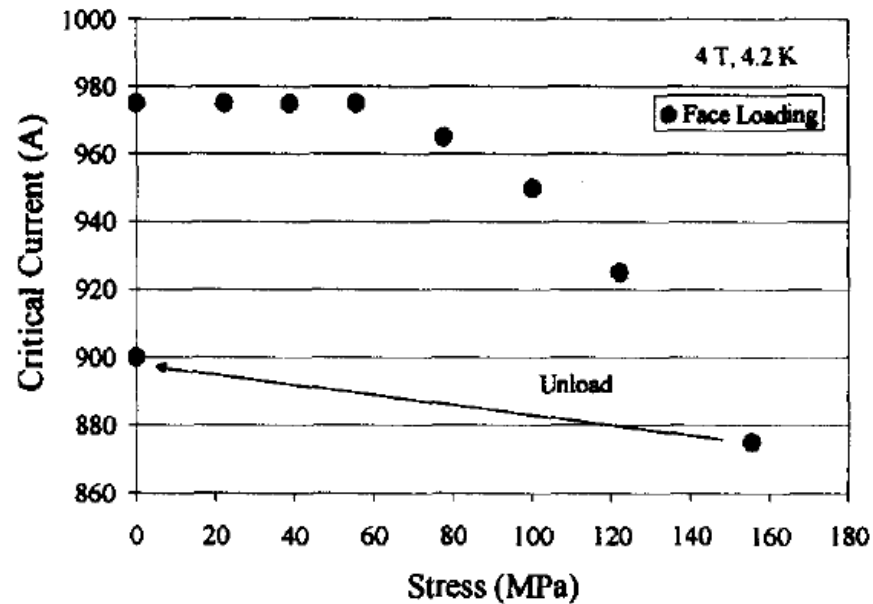
Irreversible stress limit at ~ 70 MPa

No recover of I_c after unload



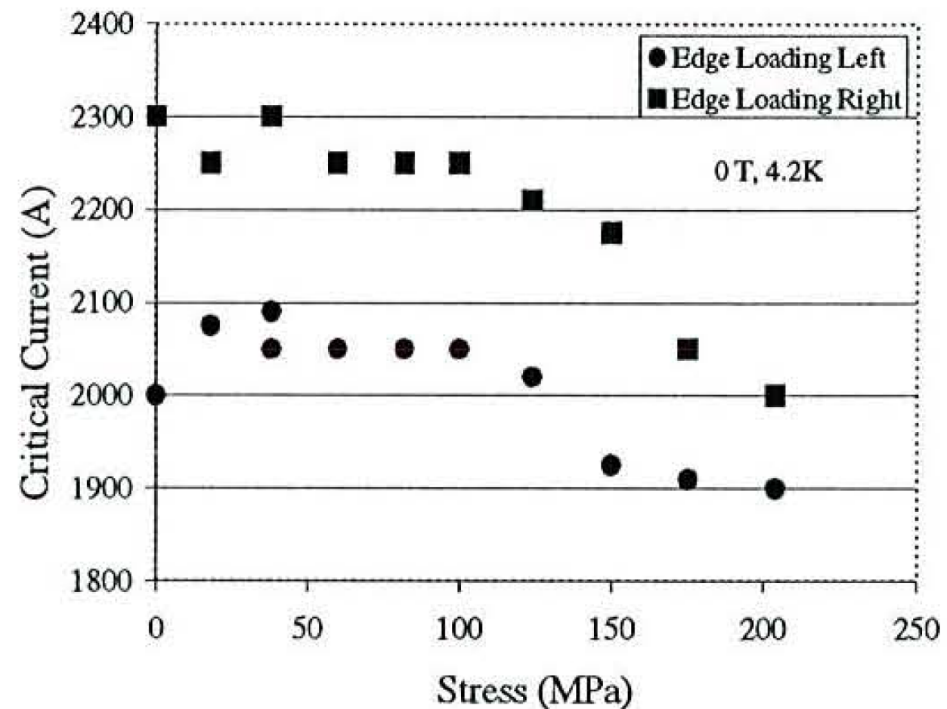
The first set of data obtained by Daniel Dietderich

- Face loading critical stress – 120 Mpa (5% I_c reduction)

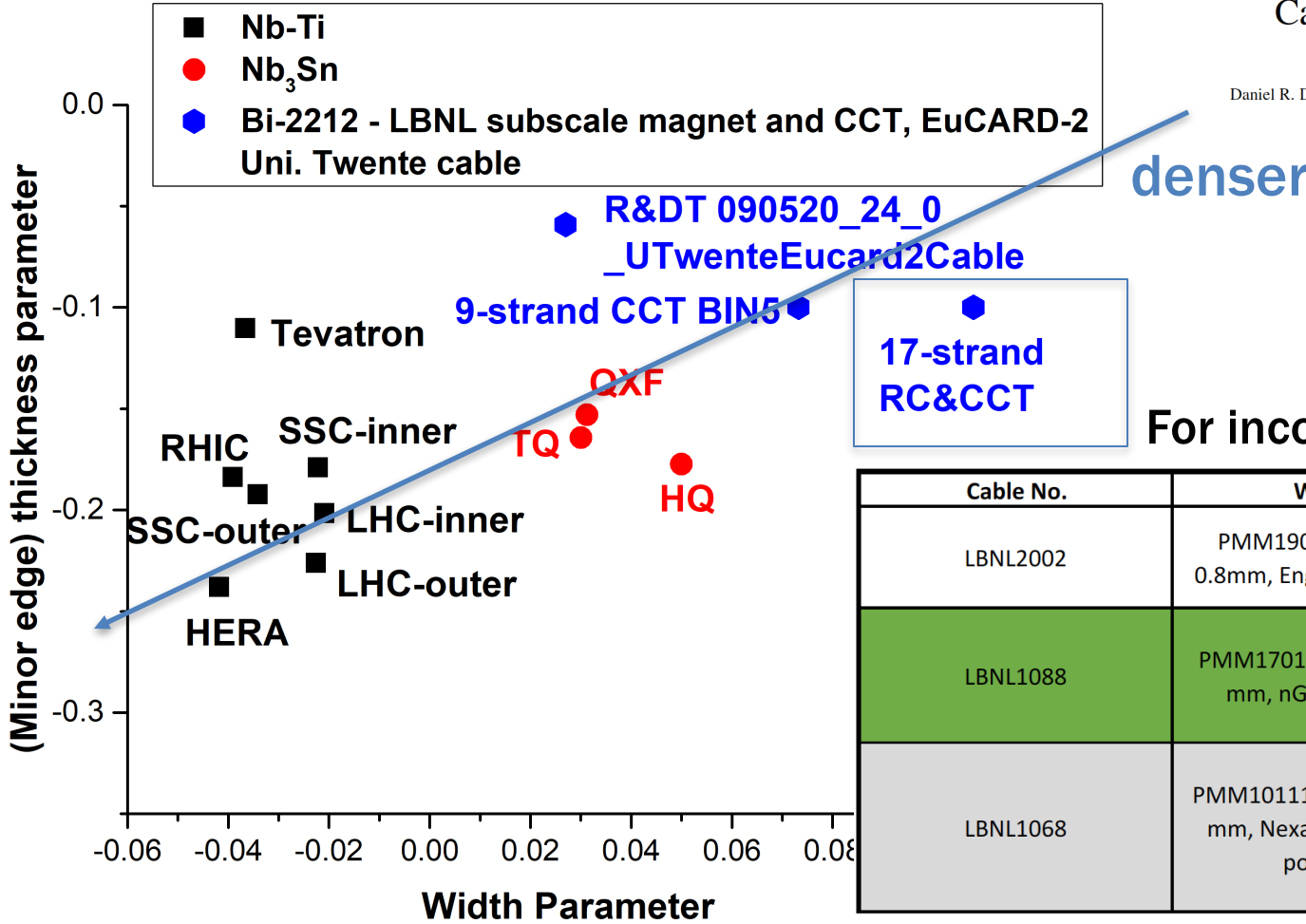


Dietderich et al., Physica C, 341-348, 2599 (2000)

- Edge loading critical stress – 160 Mpa (5% I_c reduction)



Planning of next transverse pressure tests at the Uni. Twente and Uni. Geneva



Cable R&D for the LHC Accelerator

Research Proc

Daniel R. Dietderich, Emanuela Barzi, Arup K. Ghosh,

III. CABLE PARAMETER DETERMINATION

LBNL has developed a simple empirical formula for determining an acceptable cable dimensions for the odd strand configuration. This strand configuration in Fig. 1 is the widest section of the cable and it is from this that the ideal "theoretical width" (W_{th}) is calculated in (1). The input for this calculation is the number of strands in the cable (N), the strand diameter (d), and the cable pitch angle (PA) [2]. The Width Parameter (WP) for a cable is defined by (2).

$$W_{th} = d * (N/2) * [\text{Cosine}(PA)]^{-1} \quad (1)$$

$$WP = (w - W_{th})/W_{th} \quad (2)$$

A value of $WP > 0$ means that a cable has been fabricated wider than its theoretical width and the opposite is true for values of WP less than zero.

For incoming tests:

Cable No.	Wires	Use
LBNL2002	PMM190118, 55x18, 0.8mm, Engi-mat LXB156	Will be used to construct 0.8mlong, MDPCCT3.5T
LBNL1088	PMM170123, 55x18, 0.8 mm, nGimat LXB52	Used in LBNL RC5/6, which has the record wire Jc in a magnet so far.
LBNL1068	PMM101111, 37 x 18, 0.8 mm, Nexans batch #77 powder.	Not used in any coils/magnets. Strand and cable closed to those used for LBNL RC2/3.

Three levels of questions to address

- 1. What is the critical transverse pressure of Bi-2212 Rutherford cables at 4 K?
- 2. How do Bi-2212 Rutherford cables behave under cyclic loads at 4 K?
- 3. How do the critical transverse pressure and the behavior of the cable under cyclic loads change with other technology variants, such as cable design, heat treatment, precursor powder, and microstructures of the wires?



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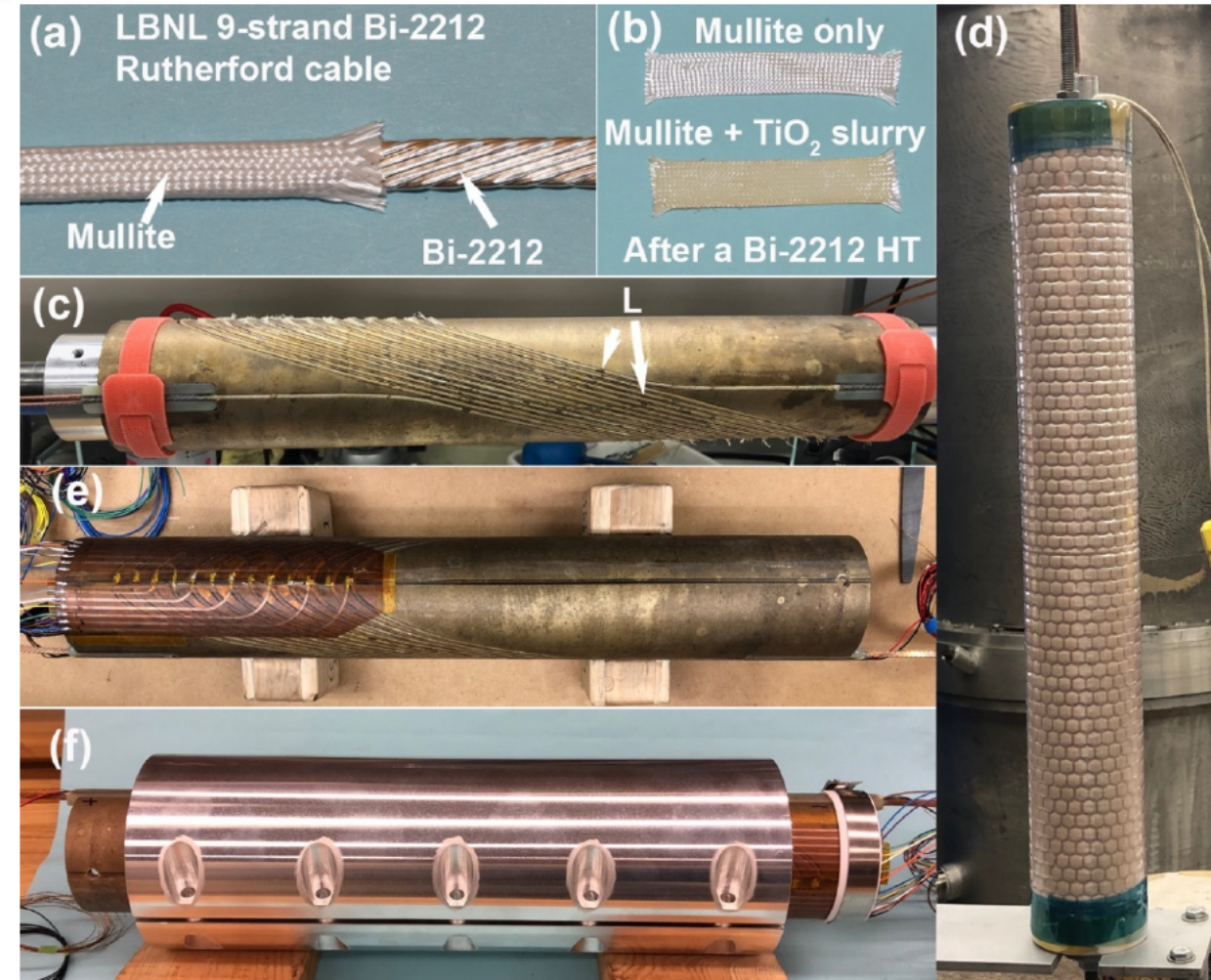
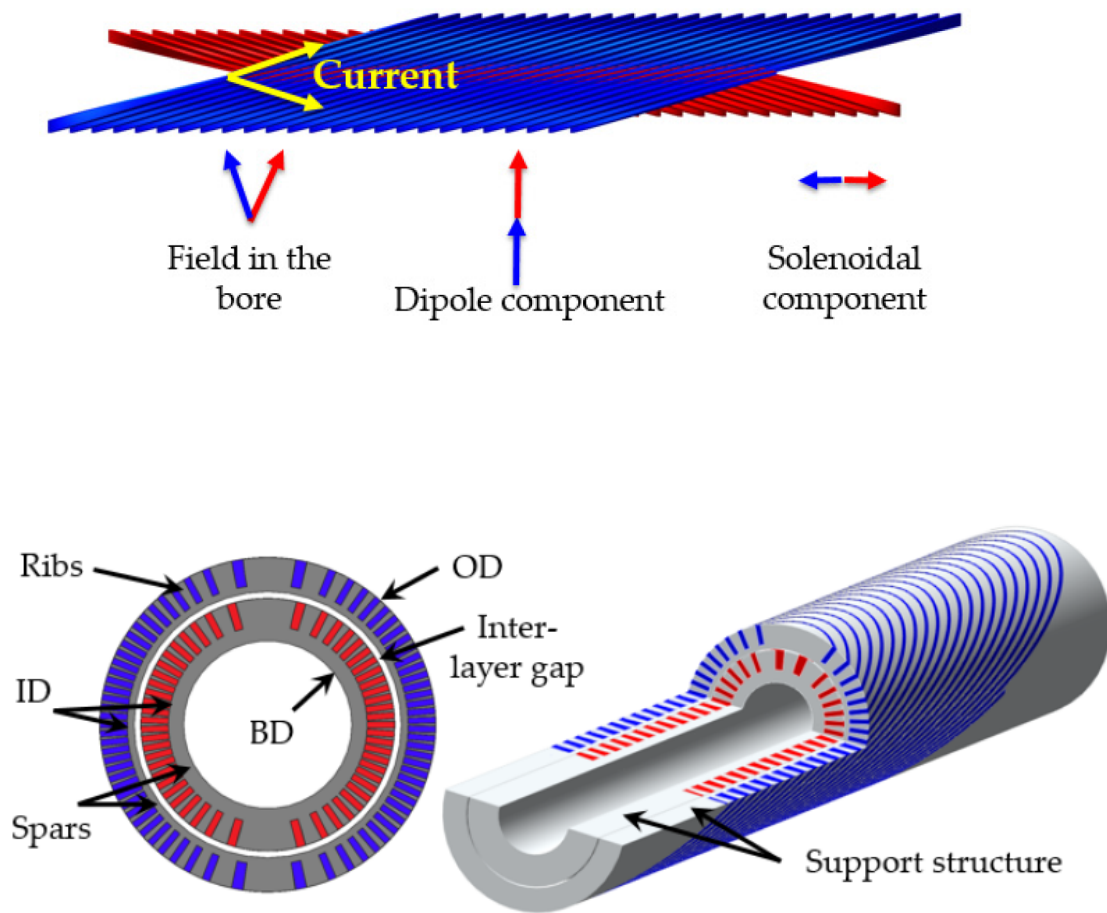


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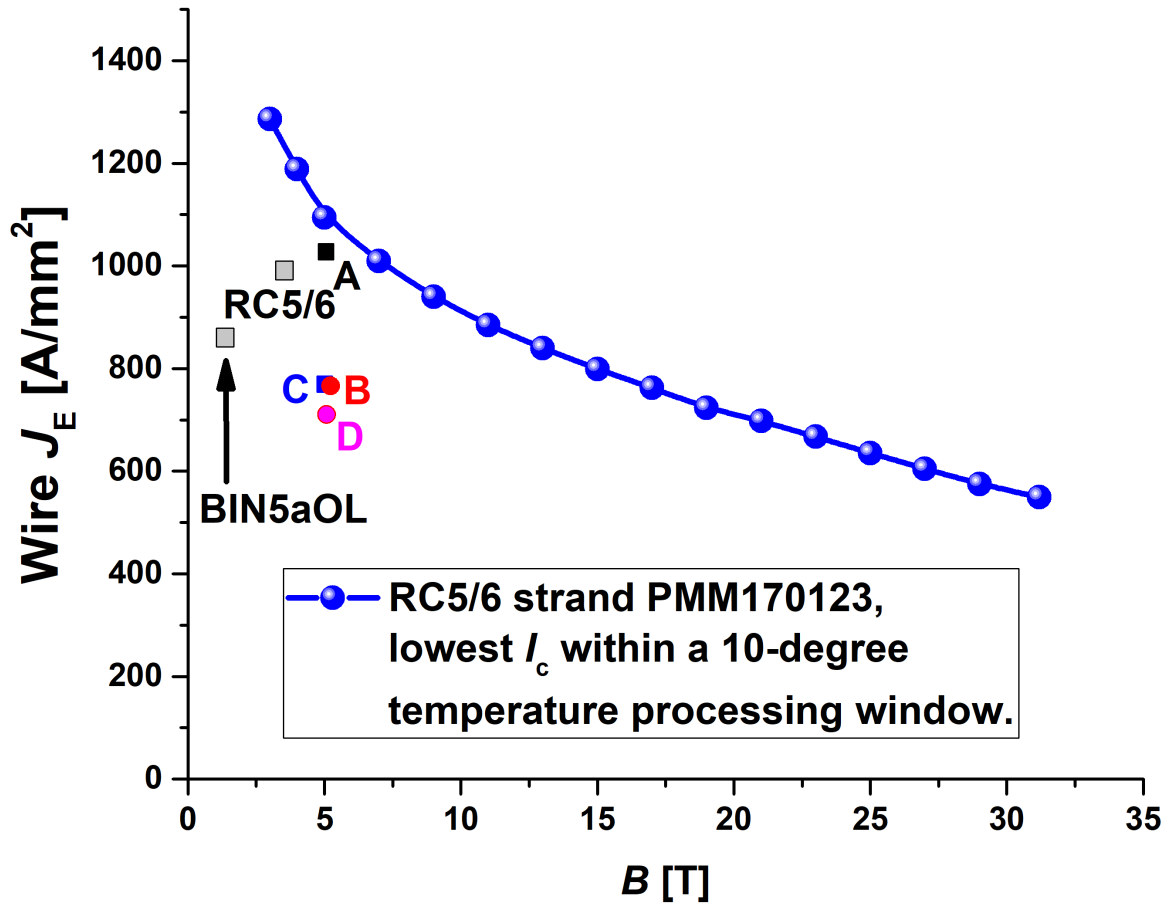


 **Fermilab**

CCT design now has gone through several prototype coils, including BIN5a and BIN5b that were reacted at the NHMFL using OP



5 T/14.6 T, ~1 m long CCT Bi-2212 dipole magnet in design phase

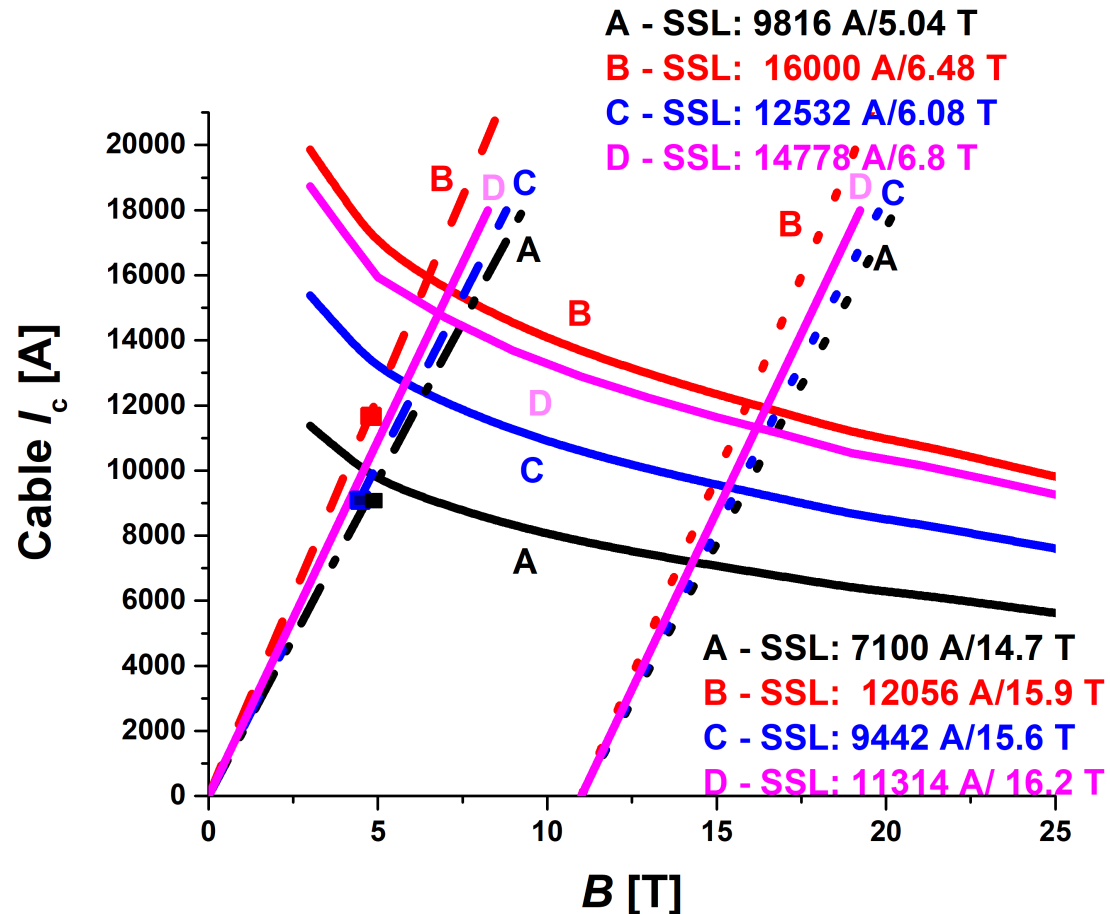


A, B, C, D are working points of four potential ~1 m long CCT dipole magnets, with the goal to achieve 5 T standalone and to provide an insert to be tested as a hybrid magnet.

A will use the LBNL subscale magnet 17-strand cable.

New cable designs for B,C,D.

Load lines of the MDP5T2212CCTdipole designs



Working points/%SSL

Standalone:

- A: 9000 A/4.64 T/92% SSL
- B: 11625 A/4.73 T/73% SSL
- C: 9000 A/4.4 T/71.8% SSL
- D: 10000 A/4.6 T/ 68% SSL

Combined with 11 T CCT6:

- A: 6530 A/92% SSL/14.4 T
- B: 8800 A/73% SSL/14.6 T
- C: 6779 A/71.8% SSL/14.3 T.
- D: 7700 A/68% SSL/14.6 T

Conductor needs – magnet by kg – inputs to CRPD.

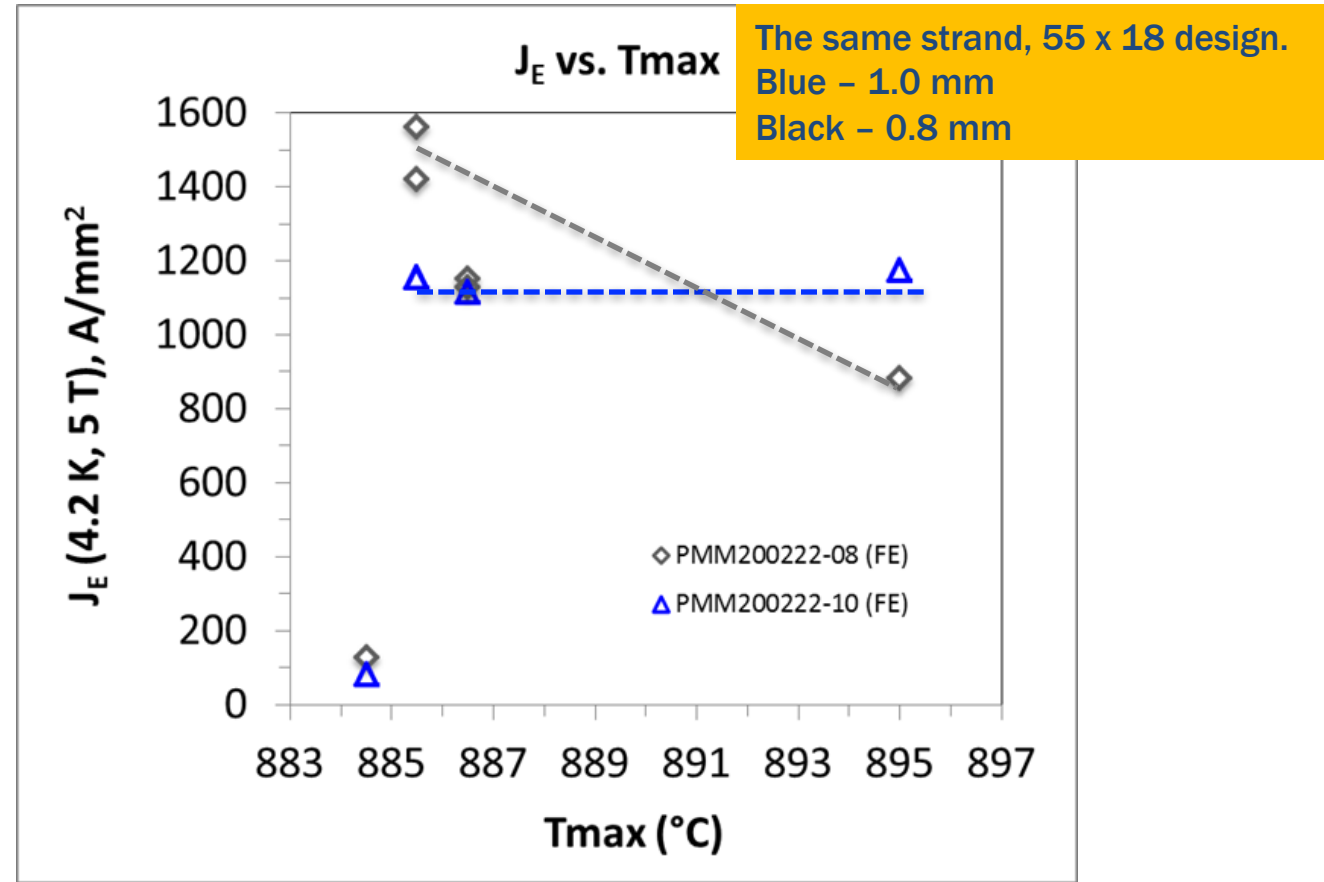
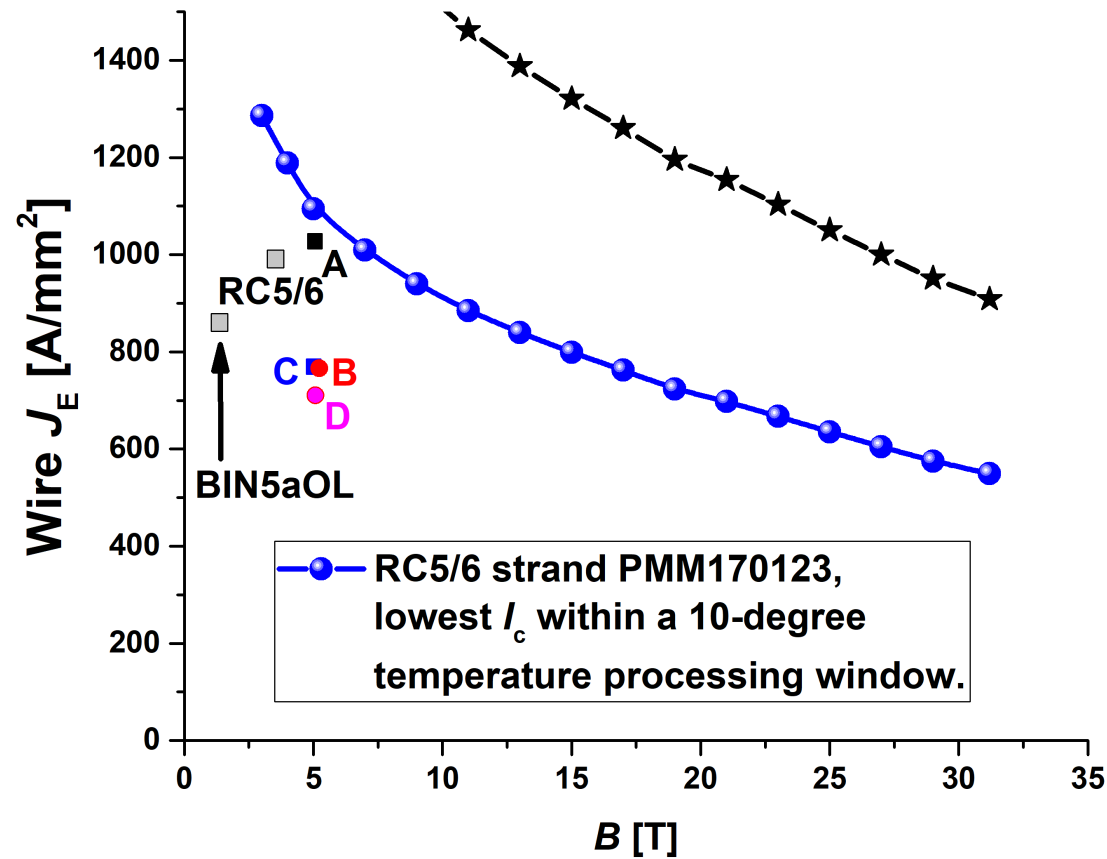
- All A/B/C/D are presumable 0.8 m long in length. To be reacted in the RENEGADE@NHMFL.

Cable	Cable ID	Strand No.	Strand diameter (mm)	Width (mm)	Thickness (mm)	Packing factor
A - LBNL subscale magnet cable	LBNL1109/2002	17	0.8	7.8	1.44	79%
B	-	19	1	10.077	1.86	82.40%
C	-	23	0.8	10.077	1.44	82.50%
D	-	28	0.8	12.25	1.44	82.60%

CCT magnet	Cable Length by meter (IL/OL/total)	Wire by meter (IL/OL/total)	Wire by kg (IL/OL/total)
A - LBNL subscale magnet cable	30/40/70	530/700/1230	2.6/3.5/6.1
B	20/29/49	450/630/1080	3.5/4.9/8.4
C	24/35/59	640/900/1540	3.2/4.5/7.7
D	23/35	760/1100/1860	3.8/5.5/9.3

- The conductor for the design A is ready. The manufacturing can start quickly. Practically it is a 3.5 T dipole.
- The conductor for the design B/C/D to be ordered.

Compared to the record wire J_E . Continual wire development is important, focusing on delivering high J_E in coils



Data courtesy of Dr. Jianyi Jiang, NHMFL. Work conducted in collaboration with Bruker OST LLC and Engi-Mat LLC.

Summary

- **International collaborations on cable transverse pressure tests moving forward.**
 - First test at the Uni. Twente projected the critical transverse pressure (the wide surface) at 130-140 MPa.
- **CCT Bi-2212 magnets in development**
 - Two ~2 T MDP Bi-2212 CCT dipole magnets (BIN5c1 and c2, LGF) are being constructed (LGF).
 - The construction of 3.5 T MDP Bi-2212 CCT dipole magnets will begin soon.
 - The planning of 5/14.6 T MDP Bi-2212 CCT dipole magnets has started. Design to be finalized pending thorough mechanical analysis. Likely will be finalized 12 months from now, hopefully after BIN5/CCT5 test.
- **Continuing conductor development is very important.**